Sizing of vent/relief lines from 1st principles

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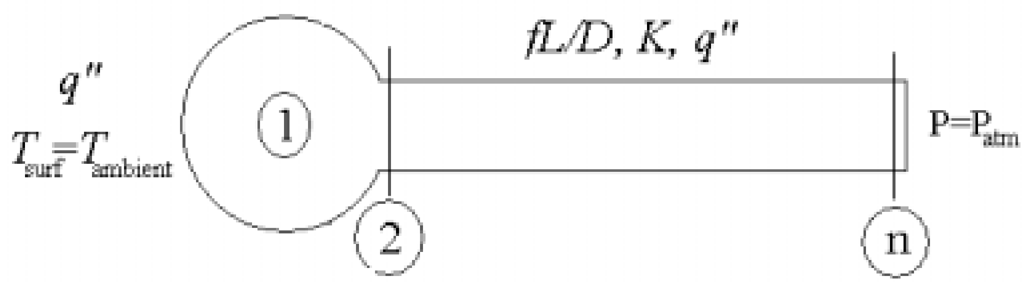
LH_2 target vessel failure modeled as a three-step process

- Expansion of 21 L of liquid from the target vessel into the 170 L vacuum vessel.
  - Modeled as an isentropic process.
  - Process maximizes the amount of liquid present in the vacuum vessel.
- Constant volume heat addition with relief devices closed.
  - Pressure increase to 20 psig.
- Relief valve opens followed by a discharge of hydrogen through the relief line.

Model Description

- A 1-D transient analysis has been developed.
- Heat transfer to the hydrogen in the vessel (node 1) results in a frictionless flow of vapor from the vessel to the relief piping.
  - Throughout the venting process the vessel wall temperature is maintained at 300 K.
  - Film boiling heat flux (8 W/cm^2) is assumed.
- Friction and heat transfer are considered in the flow through the relief piping.
  - Frictional effects modeled using loss coefficients (K) and equivalent L/D ratios for fittings and valves.
  - Heat transfer in the piping is modeled by assuming a surface temperature of 300 K.



Relief line geometry

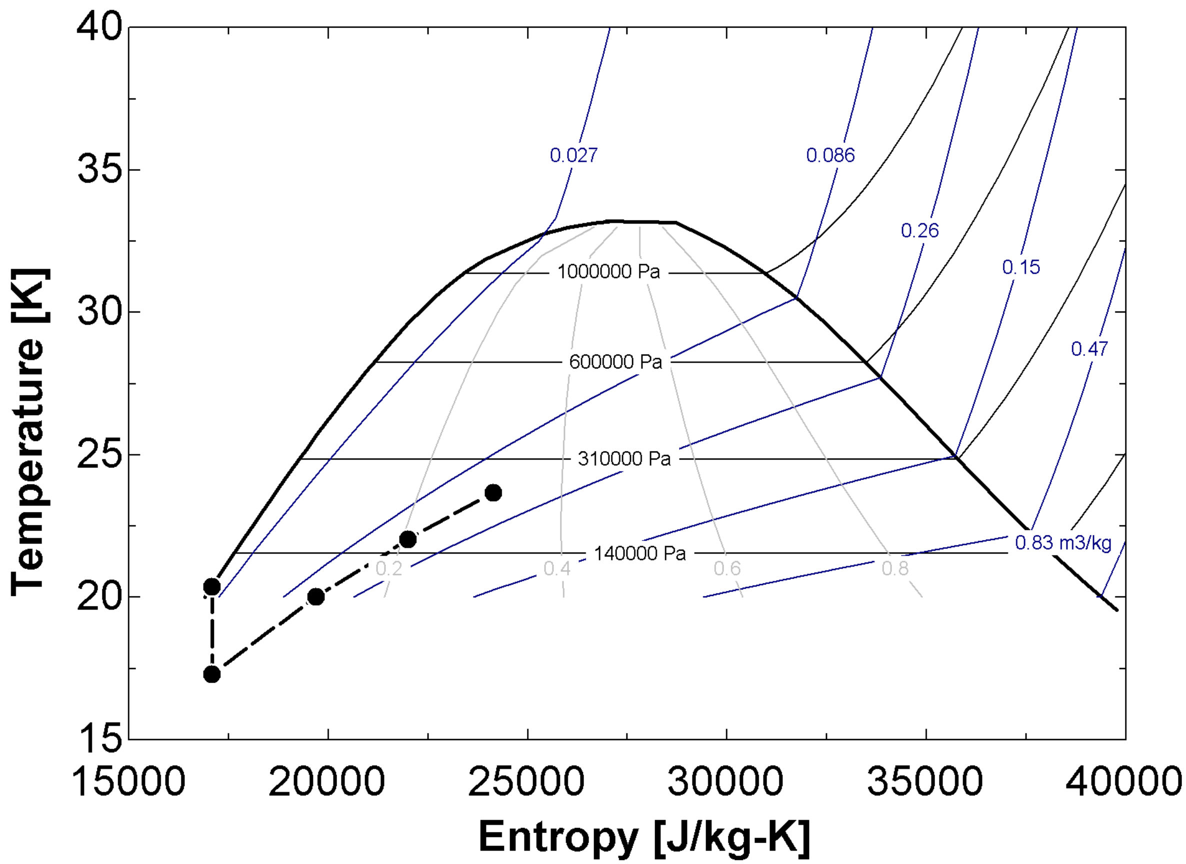
- Length (L), diameter (D), elevation change (Δh), loss coefficient (K), and equivalent lengths (L_e/D) for the various sections of relief pipe in ER2.
- Loss coefficients and equivalent lengths from: R. W. Fox and A. T. McDonald, *Introduction to Fluid Mechanics*, 4th ed., John Wiley & Sons, New York, 1992.

Section	L (ft)	D (in)	Δh (ft)	K	L_e/D	Components in Section
2 to 3	2.1	3.375	2.1	0	0	
3 to 4	0.9	4	0	3.4	60	Relief valve and flow through tee
4 to 5	30	6	0	0	630	Check valve and 90 deg. bend
5 to 6	79	6	55	0	120	Flow through tee and 2 90 deg. bends

Code Development/Validation

- Discrete form of the governing mass, momentum, and energy balance equations are solved.
- Fluid properties are obtained from the real fluid equation of state in Engineering Equation Solver (EES) software.
- Flow through the relief piping is compared to the exact solutions for Fanno and Rayleigh flow in the limiting cases of adiabatic (Fanno) and frictionless (Rayleigh) flow.
  - Results typically within 10 %.
  - Deviations attributed to real gas and transient effects.

Results: Volume expansion and constant volume heat addition



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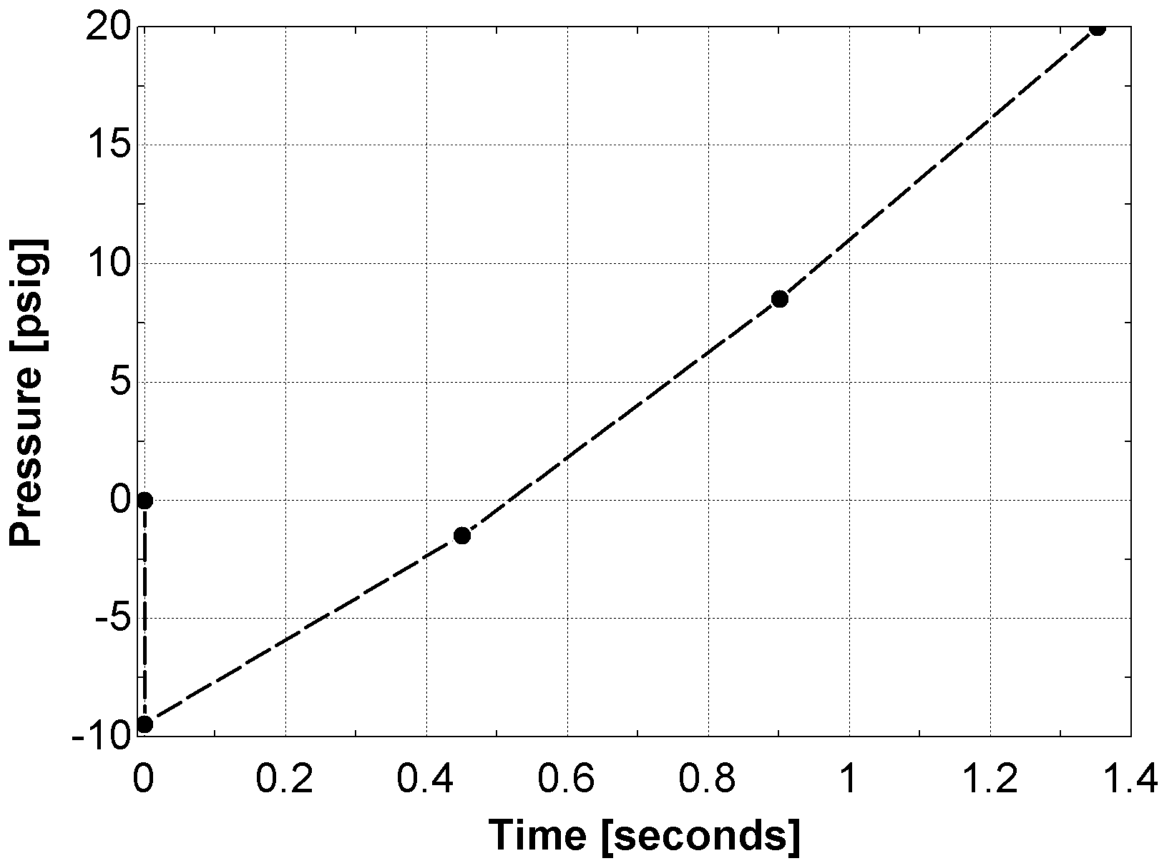
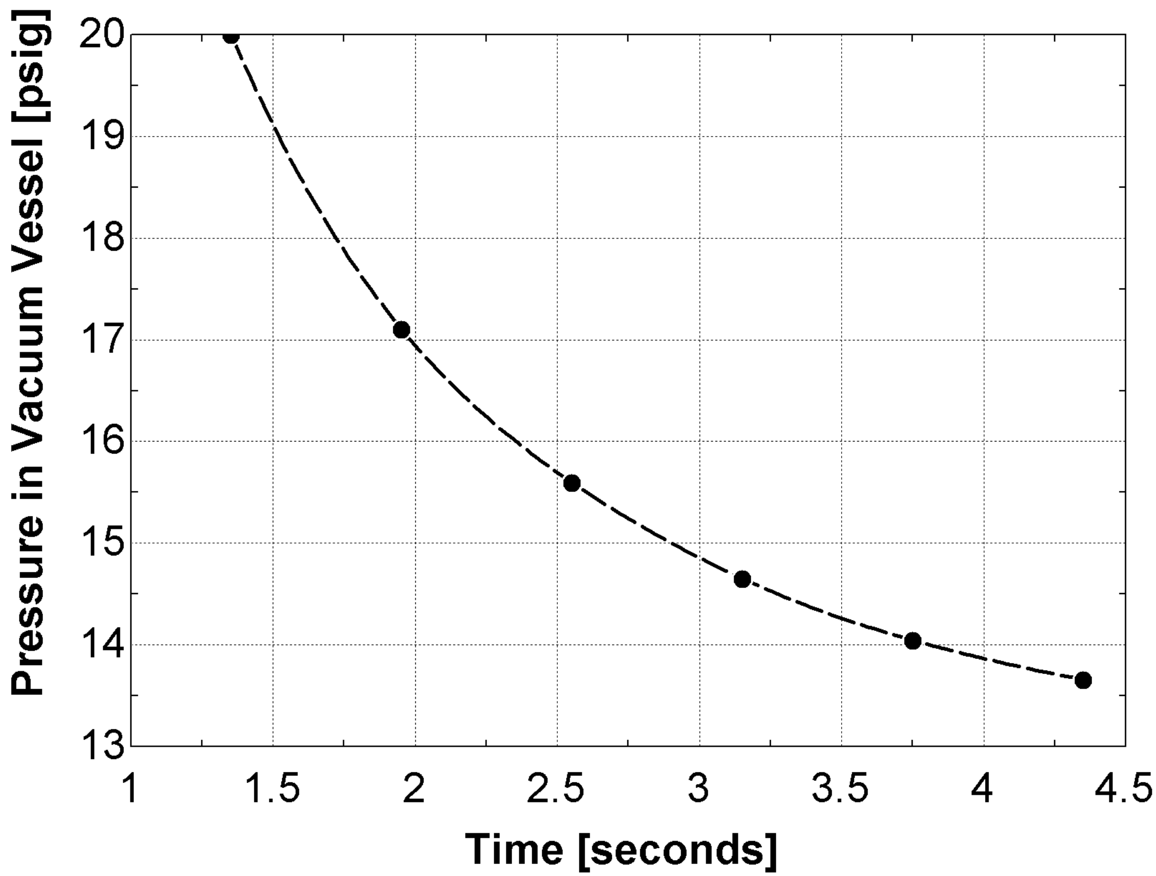


Results: Flow through the relief line



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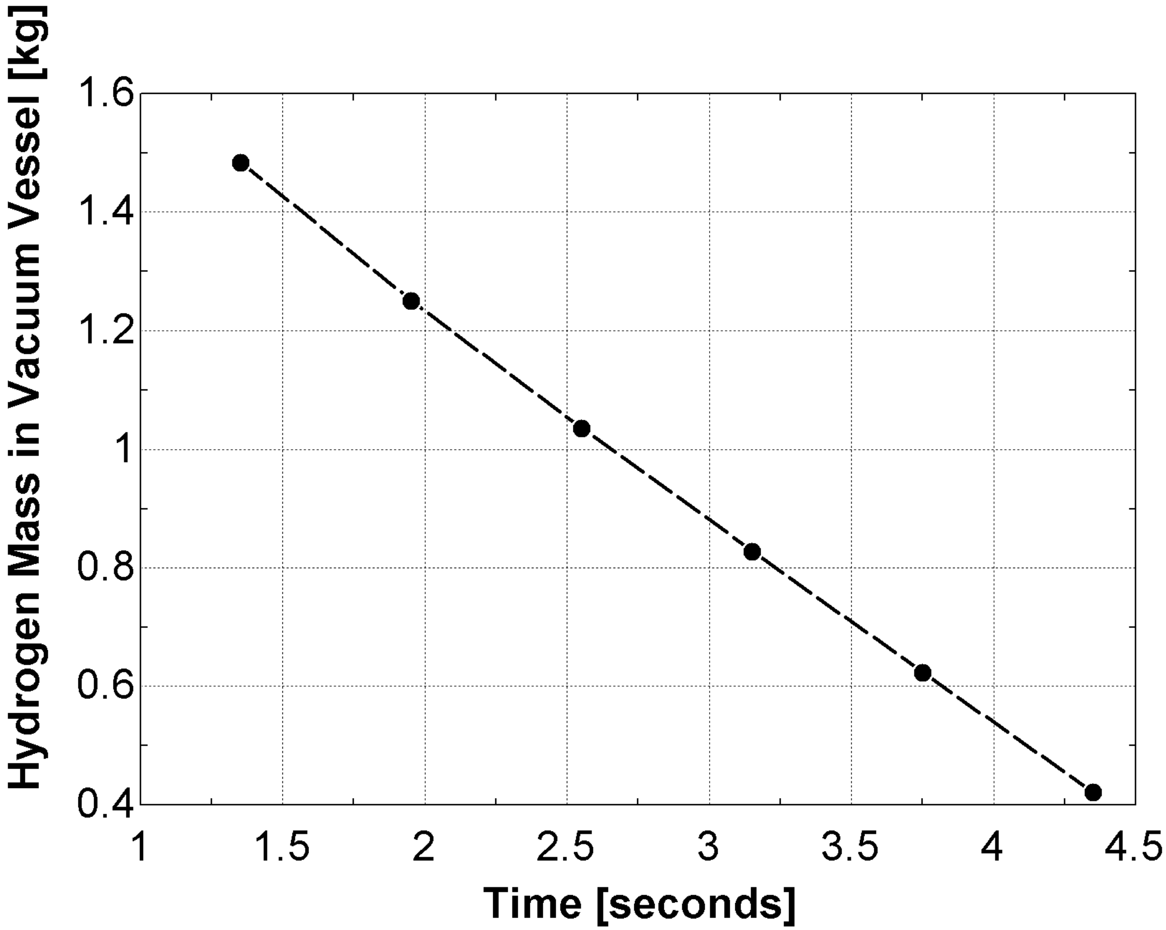

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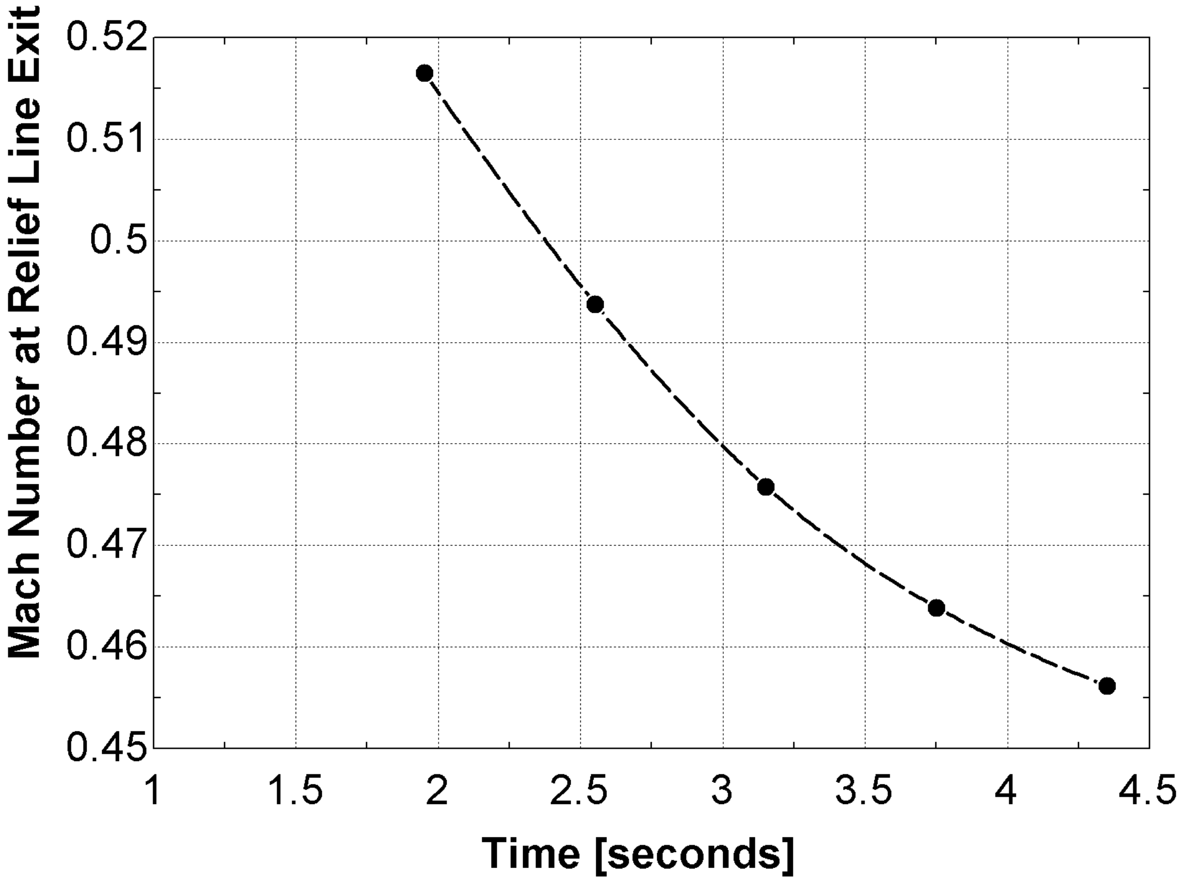

Conclusions

- A transient model has been used to analyze the relief system after a failure of the 21 L target vessel.
- Conservative assumptions have been used when possible.
- Using these assumptions, the model shows that the capacity of the relief line is adequate to handle the failure of the target vessel.